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Formation of bubbles at submerged orifices – Experimental investigation and theoretical prediction

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ABSTRACT

The present work reports an experimental investigation on bubble release through submerged orifices. Bubble frequency has been measured as a function of gas flow rate for three different orifice sizes at various pool heights. Needle type conductivity probe has been used for bubble count. Analysis of probe signal not only gives the bubble frequency but also indicates a transition from bubbling to jetting regime. Further, to validate the experimental observations a simple mechanistic model has been developed considering the evolution of non-spherical bubbles at the orifice mouth. Reasonable agreement between the model prediction and the experimental result has been observed.

1. Introduction

Release of gas bubbles through submerged apertures comprises a complex interplay of different fluid dynamic processes. This phenomenon is encountered in various process equipments like gas–liquid contractor, gas–liquid separator, bubble absorber, bubble column, fermentator etc. Interestingly, release of gas bubbles from a submerged orifice also resembles nucleate boiling. A study of the former is expected to throw some light on formation and departure of bubbles, waiting period and inception of jetting which are common for nucleate boiling.

It is not surprising that the intricate process of bubble evolution at a submerged orifice has motivated a large volume of research activities over the decades. One can trace a continuous development of the topic through experimental investigations, analytical modelling and computational simulations. In a recent review Kulkarni and Joshi [1] has discussed this phenomena in the most comprehensive manner. Nevertheless, some of the important investigations on this topic are briefly discussed in this section. Early experiments were conducted by Davidson [2], Walters and Davidson [3] and McCann and Prince [4]. Mainly the shape, the volume and the frequency of the released bubbles were estimated for a variation of different operating parameters. Effect of chamber volume was investigated by Marmur and Rubin [5] while Akagi et al. [6] and Che and Chen [7] carried out some experiments to understand the weeping rate as well as the effect of chamber volume on the process of bubbling. Kumar and Kuloor [8] and Terasaka and Tsuge [9] reported some detailed review of the previous experimental studies. But all these experiments depend on the visual observation for calculation of bubble frequency. As the individual pattern of the bubble period is not monitored the qualitative comparison of experimental data for the development of basic understanding of the process was not possible.

McCann and Prince [3], Kupferberg and Jameson [10] and LaNauze and Harris [11] attempted to analyze the process based on simplified assumptions. But most of these models are very case sensitive and treat the bubble as a gaseous spherical lump. Marmur and Rubin [12] relaxed the limitation of spherical growth considering the local motion of the gas liquid interface and introduced the concept of “added mass”. Their model can also predict the transition from characteristics of single bubble to bubble jetting region. Subsequently, Tan and Harris [13], Pinczewski [14], Terasaka and Tsuge [9] proposed different models dividing the bubble interface into a number of elements (interfacial element method). Though these models accounted the growth of non-spherical bubble, the mechanism of various bubble behaviors at submerged orifices remains far from fully understood.

The model of Zhang and Tan [15] applied the potential flow theory to describe the bubble formation, its growth and departure. They used Oseen’s modification [16] to potential flow to propose detachment criteria for a growing bubble. Liquid weeping and wake pressure due to departing bubble is accounted in their model

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